CHARACTERISTIC OF PALM OIL METHYL ESTER AS ALTERNATIVE FUEL

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I certify that the project entitled "*Characteristic Of Palm Oil Methyl Ester As Alternative Fuel*" is written by *Muhammad Rizuan Bin Musa*. I have examined the final copy of this project and in our opinion; it is fully adequate in terms of scope and quality for the award of the degree of Bachelor of Engineering. I herewith recommend that it be accepted in partial fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering with Automotive.

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STUDENT'S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

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ABSTRACT

The purpose of this work is to define the relationship between the fuel physical properties and the atomization characteristic of biodiesel. The spray atomization behavior was analyzed through spray parameters such as the spray tip penetration, cone angle and droplet size. Besides that, the specific heat capacity, viscosity, specific heat profile and liquid property profile is determined to define the characteristic of palm oil and also to prepare the database of palm oil. These parameters were obtained from an injector tester system and accurate prediction of spray atomization. In addition, the experimental results of biodiesel were compared with the diesel and cooking oil. It was revealed that the increase of the pressure supply (from 100 bar to 400 bar) little affects the spray liquid tip penetration. The increase of the pressure supply also increases the complete combustion. Also, biodiesel fuel evaporation actively occurred due to the increase in the pressure supply. Besides that, palm oil methyl ester possesses a high boiling point compare to diesel and this has showed that the fuel chemical structure and critical properties significantly influences the fuel properties.

ABSTRAK

Tujuan laporan ini adalah untuk menentukan hubungan antara sifat fizikal bahan bakar dan ciri-ciri atomisasi biodiesel. Perilaku semburan atomisasi dianalisis melalui parameter spray seperti penetrasi hujung semburan, sudut kon dan saiz titisan. Selain itu, kapasiti panas khusus, kelikatan, panas khusus profil dan profil hotel cair bertekad untuk menentukan ciri-ciri minyak sawit dan juga untuk menyediakan pangkalan data kelapa sawit. Parameter ini boleh diperolehi dari sistem pengujian penyuntikan dan ramalan yang tepat dari semburan atominasi. Selain itu, keputusan eksperimen antara biodiesel telah dibandingkan dengan diesel dan minyak masak. Terbukti bahawa peningkatan tekanan yang diberikan (dari 100 bar sehingga 400 bar) sedikit mempengaruhi tembusan hujung semburan cair. Kenaikan kadar tekanan juga meningkatkan pembakaran yang sempurna. Juga, pengewapan bahan bakar biodiesel aktif berlaku kerana peningkatan kadar tekanan. Selain itu, kelapa sawit metil ester mempunyai takat didih yang tinggi berbanding dengan diesel dan hal ini menunjukkan bahawa struktur kimia bahan bakar dan sifat kritikal nyata sekali mempengaruhi sifat bahan bakar.

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LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Materials
B80	80% biodiesel and 20% petrodiesel
EC	European Community
FAME	Fatty acid methyl esters
HHVs	Higher heating values
LPG	Liquefied petroleum Gas
MPOB	Malaysia Palm Oil Board
NG	Natural gas
POME	Palm Oil Methyl Ester
PORIM	Palm Oil Research Institute of Malaysia
SMD	Sauter Mean Diameter

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

If the agricultural products market is limited and much of agricultural land is not utilized as is the case in many countries in the world at present, then agriculture should be directed to the production of new alternative products. The land can be used to produce non-food products including biodiesels for the domestic energy market to diminish imports. Much research has been done on biodiesels over the last 20 year after the oil crisis in 1973. At present, concern about environmental regulations has been the major reason to look for alternative fuel. A property of biodiesel has been obtained but there is a lack of full or partial replacement of fossil fuel that needs to be discussed (M.A. Kalam, 2002).

This research is presents the results of the experimental of the characteristic of palm oil methyl ester as an alternative fuel. This biodiesel is defined as the methyl ester of palm oil also known as palm oil diesel. The results of this investigation will be used to find compatible lubricant for biodiesel engine.

Palm oil is one of the most popular fuels in this world. Palm oil can produced the variety of product and is widely use as cooking oil. Palm oil like other vegetable oils can be used to create biodiesel for internal combustion engines. Biodiesel has been promoted as renewable energy source to reduce net emissions of carbon dioxide into atmosphere. Therefore, biodiesel is seen as a way to decrease the impact of the greenhouse effect and as a way of diversifying energy supplies to assist national energy security plans.

Methyl esters derived from vegetable oil (biodiesel) have good potential as an alternative diesel fuel. The cetane number, energy content, viscosity, and phase changes of biodiesel are similar to those of petroleum based diesel fuel (D. Darnoko, 2000). Biodiesel is produced by transesterification of large, branched triglycerides (TG) into smaller, straight chain molecules of methyl esters, using an alkali or acid as catalyst (Munir Cheryan, 2000).

In 1983, the Palm Oil Research Institute of Malaysia (PORIM) successfully converted crude palm oil to palm oil methyl ester (POME) through transesterification. The transesterification shortens the molecular chain from about 57 to about 20, reducing the viscosity and improving the thermal stability. The sulphur content in POME is very low (1.112 wt %), making it less pollutant and more environmentally friendly. However, the cetane number of this POME is relatively low (50-52) compared with ordinary diesel (53) (H.H. Masjuki, 1996).

1.2 PROBLEM STATEMENT

Fuel physical properties and the atomization characteristic of biodiesel are attributes that requires thorough scrutiny in order to be determined. Discreet observation is required to obtain the specific heat profile, specific heat capacity value and liquid property profile in order to define the properties of biodiesel. On the other hand, predicting the physical properties of the vegetables oils and biofuels is crucial in the accurate prediction of the spray atomization.

1.3 SCOPES OF STUDY

The scope of study in this research can be obtained as:

- Collect all characteristics information from the literature.
- Characteristics testing of biodiesel fuel.
- Define and predict the properties of biodiesel.

1.4 OBJECTIVES OF THE PROJECT

The objectives of this research are:

- To determine the spray pattern characteristics of palm oil.
- To prepare a major database of palm oil against other biodiesel sources.
- To investigate fuel spray pattern in order to obtain the cone angle, spray tip penetration and droplet size.

CHAPTER 2

LITREATURE RIVIEW

2.1 BIODIESEL

2.1.1 Introduction to Biodiesel Concept

The scarcity of conventional fossil fuels, growing emissions of combustion generated pollutants and their increasing costs will make biomass sources more attractive (Sensoz, 2000). On the other hand, biomass use in which many people already have an interest has properties of being a biomass source and a carbon-neutral source (Dowaki, 2007). Experts suggest that current oil and gas reserves would suffice to last only a few more decades. To meet the rising energy demand and replace reducing petroleum reserves, fuels such as biodiesel and bioethanol are in the forefront of alternative technologies. Accordingly, the viable alternative for compression-ignition engines is biodiesel.

Biodiesel is briefly defined as the monoalkyl esters of vegetable oils or animal fats. Biodiesel is the best candidate for diesel fuels in diesel engines. Biodiesel burn like petroleum diesel as it involves regulated pollutants. On the other hand, biodiesel probably has better efficiency than gasoline. Biodiesel also exhibits great potential for compression-ignition engines. Diesel fuel can also be replaced by biodiesel made from vegetable oils. Biodiesel is now mainly being produced from soybean, rapeseed and palm oils. The higher heating values (HHVs) of biodiesel are relatively high. The HHVs of biodiesel (39 to 41 MJ/kg) are slightly lower than those of gasoline (46 MJ/kg), petrodiesel (43 MJ/kg), or petroleum (42 MJ/kg), but higher than coal (32 to 37 MJ/kg).

Biodiesel is pure or 100%, biodiesel fuel. It is referred to as B100 or “neat” fuel. A biodiesel blend is pure biodiesel blended with petrodiesel. Biodiesel blends are referred to as BXX. The XX indicates the amount of biodiesel in the blend (*i.e.*, a B80 blend is 80% biodiesel and 20% petrodiesel).

The majority of energy demand is fulfilled by conventional energy sources like coal, petroleum, and natural gas. Petroleum-based fuels are limited reserves concentrated in certain regions of the world. These sources are on the verge of reaching their peak production. The scarcity of known petroleum reserves will make renewable energy sources more attractive (Sheehan, 1998).

World energy demand continues to rise. The most feasible way to meet this growing demand is by using alternative fuels. One such fuels that exhibits great potential is biofuel, in particular biodiesel (Fernando, 2006). The term biofuel can refer to liquid or gaseous fuels for the transport sector that are predominantly produced from biomass (Demirbass, 2006). In developed countries there is a growing trend towards using modern technologies and efficient bioenergy conversion using a range of biofuels, which are becoming cost wise competitive with fossil fuels (Puhan, 2005).

It is well known that transportation is almost totally dependent on fossil, particularly petroleum based fuels such as gasoline, diesel fuel, liquefied petroleum gas (LPG), and natural gas (NG). An alternative fuel to petrodiesel must be technically feasible, economically competitive, environmentally acceptable, and easily available. The current alternative diesel fuel can be termed biodiesel. Biodiesel use may improve emissions levels of some pollutants and deteriorate others. However, for quantifying the effect of biodiesel it is important to take into account several other factors such as raw material, driving cycle and vehicle technology. Use of biodiesel will allow a balance to be sought between agriculture, economic development, and the environment (Meher, 2006).

2.1.2 History of Biodiesel

The process for making fuel from biomass feedstock used in the 1800s is basically the same one used today. The history of biodiesel is more political and economical than technological. The early 20^{th} saw the introduction of gasoline powered automobiles. Oil companies were obliged to refine so much crude oil to supply gasoline that they were left with a surplus of distillate, which is an excellent fuel for diesel engines and much less expensive than vegetable oils. On the other hand, resource depletion has always been a concern with regard to petroleum and farmers have always sought new markets for their products. Consequently, work has continued on the use of vegetable oils as fuel.

Producing biodiesel from vegetable oils is not a new process. The conversion of vegetable oils or animal fats into monoalkyl esters or biodiesel is known as transesterification. Transesterification of triglycerides in oils is not a new process. Duffy and Patrick conducted Transesterification as early as 1853. Life for the diesel engine begins in 1893, when the famous German inventor Dr. Rudolph Diesel published a paper entitled “The theory and construction of a rotational heat engine”. The paper described a revolutionary engine which air would be compressed by a piston to a very high pressure, thereby causing a high temperature. Dr. Diesel designed the original diesel to run on vegetable oil.

Dr. Diesel was educated at the predecessor school to the Technical University of Munich in Germany. In 1878, he was introduced to the work of Sadi Carnot, who theorized that an engine could achieve much higher efficiency than the steam engines of the day. Diesel sought to apply Carnot’s theory to the internal combustion engine. The efficiency of the Carnot cycle increases with the compression ratio-the ratio of gas volume at full expansion to its volume at full compression. Nicklaus Otto invented an internal combustion engine in 1876 that was the predecessor to the modern gasoline engine. Otto’s engine mixed fuel and air before their introduction to the cylinder and a flame or spark was used to ignite the fuel air mixture at the appropriate time. However, air gets hotter as it is compressed and if the compression ratio is too high, the heat of compression will ignite the fuel prematurely. The low compression needed to prevent premature ignition of the fuel air mixture limited the efficiency of the Otto engine. Dr. Diesel wanted to build an engine with the highest possible compression ratio. He introduced fuel only when combustion was desired and allowed the fuel to ignite on its own in the hot compressed air. Diesel's engine achieved efficiency higher than that of the steam engine. Diesel received a patent in 1893 and demonstrated a workable engine in 1897. Today, diesel engines are classified as "compression-ignition" engines, and Otto engines are classified as "spark-ignition" engines.

Dr. Diesel used peanut oil to fuel one of his engines at the Paris Exposition of 1900 (Nitschkae and Wilson, 1965). Because of the high temperature created, the engine was able to run a variety of vegetable oils including hemp and peanut oil. At the 1911 World's Fair in Paris, Dr. Diesel ran his engine on peanut oil and declared "the diesel engine can be fed with the vegetable oils and will help considerably in the development of the agriculture of the countries with use it". One of the first uses of transesterified vegetable oil was powering heavy duty vehicles in South Africa before World War II. The name "biodiesel" has been given to transesterified vegetable oil to describe its use as a diesel fuel (Demirbas, 2002). Vegetable oils were used in diesel engines until the 1920s. During the 1920s, diesel engine manufactures altered their engines to utilize the lower viscosity of petrodiesel, rather than vegetable oil.

The use of vegetable oils as an alternative renewable fuel competing with petroleum was proposed in the early 1980s. The advantages of vegetable oils as diesel fuel are its portability, ready availability, renewability, higher heat content (about 88% of No. 2 petroleum diesel fuel), lower sulphur content, lower aromatic content and biodegradability. The energy supply concerns of the 1970s renewed interest in biodiesel but commercial production did not begin until the late 1990s.

Dr. Diesel believed that the engines running on plant oils had potential and that these oils could one day be as important as petroleum based fuels. Since the 1980s, biodiesel plants have opened in many European countries and some time cities have run buses on biodiesel or blends of petro and biodiesels. Most recently, Renault and Peugeot have approved the use of biodiesel in some of their truck engines. Recent environmental and domestic economic concerns have prompted resurgence in the use of biodiesel throughout the world. In 1991, the European Community (EC) proposed a 90% tax deduction for the use of biofuels, including biodiesel. Biodiesel plants are now being built by several companies in Europe; each of these plants will produce up to 1.5 million gallons of fuel per year. The European Union accounted for nearly 89% of all biodiesel production worldwide in 2005.

2.1.3 Definition of Biodiesel

Biodiesel refers to a diesel-equivalent, processed fuel derived from biological sources. Biodiesel is the name for variety of ester-based oxygenated fuels from renewable biological sources. It can be made from processed organic oils and fats.

Chemically, biodiesel is defined as the monoalkyl esters of long-chain fatty acids derived from renewable biolipids. Biodiesel is typically produced through the reaction of a vegetable oil or animal fat with methanol or ethanol in the presence of a catalyst to yield methyl or ethyl esters (biodiesel) and glycerine (Demirbas, 2002). Fatty acid methyl esters or biodiesels are produced from natural oils and fats. Generally, methanol is preferred for transesterification because it is less expensive than ethanol (Graboski and McCormick, 1998).

In general term, biodiesel may be defined as a domestic and renewable fuel for diesel engines derived from vegetable oil which meets the specification of ASTM D 6751 (Fukuda, 2001). Biodiesel consists of alkyl esters, which are produced from the transesterification reaction between triglycerides and alcohol. In experimental studies, the final product is term as fatty acid alkyl esters or fatty acid methyl esters (FAME) instead of biodiesel unless it meets the specification of ASTM D6751 (Lois, 2007). Biodiesel, in application as an extender for combustion in CIEs (diesel), possesses a number of promising characteristics, including reduction of exhaust emissions (Dunn, 2001). Chemically, biodiesel is referred to as the monoalkyl esters, especially methyl ester of long chain fatty acids derived from renewable lipid sources via a transesterification process.

Table 2.1: Technical properties of biodiesel

Technical properties	Description
Common name	Biodiesel (bio-diesel)
Common chemical name	Fatty acid (m)ethyl ester
Chemical formula range	$C_{14} – C_{24}$ methyl ester or $C_{15} – C_{25} H_{28-48} O_2$
Kinematic viscosity range (mm^2/s, at 313K)	3.3 – 5.2
Density range (kg/m^3, at 288K)	860 – 894
Boiling point range (K)	>475
Flash point range (K)	430 – 455
Distillation range (K)	470 – 600
Vapour pressure (mm Hg, at 295K)	<5
Solubility in water	Insoluble in water
Physical appearance	Light to dark yellow, clear liquid
Odor	Light musty or soapy odor
Biodegradability	More biodegradable than petroleum diesel
Reactivity	Stable but avoid strong oxidation agents

Source: Demirbas (2003)

Biodiesel is mixture of methyl esters of long-chain fatty acids like lauric, palmitic, stearic, oleic, *etc.* Typically examples are rapeseed oil, canola oil, soybean oil, sunflower oil, palm oil and their derivatives from vegetable sources. Beef and sheep tallow and poultry oil from animal sources and cooking oil are also sources of raw materials. The chemistry of conversion into biodiesel is essentially the same. Oil or fat reacts with methanol or ethanol in the presence of sodium hydroxide or potassium hydroxide catalyst to form biodiesel, methyl esters and glycerine.

2.1.4 Biodiesel As An Alternative to Diesel Fuel Engine

Biodiesel is a processed fuel that can be readily use in diesel-engine vehicles, which distinguishes biodiesel from the straight vegetable oils or waste vegetable oils used as fuels in some modified diesel vehicles. In general, the physical and chemical properties and the performance of ethyl esters are comparable to those of the methyl esters. Methyl and ethyl esters have almost the same heat content. The viscosities of ethyl esters are slightly higher and the cloud and pour points are slightly lower than those of the methyl esters. Engine test have demonstrated that methyl esters produce slightly higher power and torque than ethyl esters.

Biodiesel is a clear amber-yellow liquid with a viscosity similar to that of petrodiesel. Biodiesel is non-flammable and in contrast to petrodiesel is non-explosive, with a flash point of 423K for biodiesel as compared to 337K for petrodiesel. Unlike petrodiesel, biodiesel is biodegradable and non-toxic and it significantly reduces toxic and other emissions when burned as a fuel. Currently, biodiesel is more expensive to produce than petrodiesel, which appears to be the primary factor in preventing its more widespread use. Current worldwide production of vegetable oil and animal fat is not enough to replace liquid fossil fuel use (maximum replacement percentage: 20% to 25%) (Bala, 2005).

Methyl esters of vegetable oils (biodiesels) have several outstanding advantages among other new-renewable and clean-engine fuel alternatives. Methanol as a monoalcohol is generally used in the transesterification reaction of triglycerides in the presence of alkali as a catalyst (Clark, 1984). Methanol is a relatively inexpensive alcohol. Several common vegetable oils such as sunflower, palm, rapeseed, soybean, cottonseed and corn oils and their fatty acids can be used as the sample of vegetable oil. Biodiesel is easier to produce and cleaner with equivalent amount of processing when starting with clean vegetable oil. Tallow, lard and yellow grease biodiesels require additional processing at the end of the transesterification process due to the presence of high free fatty acids. Diesel derived from rapeseed oil is the most common biodiesel available in Europe while soybean biodiesel predominates in the United States.

Biodiesel has significant potential for use as an alternative fuel in compression-ignition engines (Demirbas, 2003). Biofuels are non-toxic, biodegrable and free of sulphur and carcinogenic compound (Venkataraman, 2002) as they are obtained from renewable sources. Biodiesel is a plant-derived product and contains oxygen in its molecules, making it a cleaner-burning fuel than petrol and diesel (Sastry, 2006).

Biodiesel is a clean burning alternative fuel produced from domestic, renewable resources that are much more efficient to produce and use than gasoline. The development history of biodiesel is more political than technological. The actual process for making biodiesel was originally developed in the early 1800s and has basically remained unchanged. It was the political and economic influences of industrial leaders during the 1920s and 1930s that caused the fuel trends to favour the use of petroleum-based fuels as opposed to agricultural fuels.

2.1.5 Advantages And Disadvantages of Biodiesel

Biodiesel is a sustainable energy (Hanna, 1999) that is made from renewable sources such as vegetable oils and animal fats. These sources could always be re-planted or grown to ensure its sustainability. Besides that, biodiesel is a non-toxic and clean energy (Omer, 2008). The emissions from vehicles that are using biodiesel contain lower harmful gases such as carbon monoxide, sulfur dioxide (Demirbas, 2007) and aromatic content (Hanna, 1999) compared to that of using petroleum derived diesel. Biodiesel could also reduce the emission of particulate matters (PM).

Biodiesel also acts as a good lubricant to diesel engines. This could therefore prologue the self-life of the engines. Biodiesel also has higher flash point which makes it safer to handle compared diesel (Jamal, 2008). Other advantages of biodiesel as diesel fuel are liquid nature portability, readily available, renewability, higher combustion efficiency (Agarwal, 2008), higher cetane number (Knothe, 2003) and higher biodegradability.

On the other hand, disadvantages of biodiesel include increased emission of NO_x gas, higher cloud and pour points (Hanna, 1999) and also costlier compared to diesel due to high price of vegetable oils especially those of edible type. However, the cost of biodoesel could vary depending on the source of feedstock (Demirbas, 2008). Biodiesel could also dissolve certain parts of the diesel engines, especially those made of elastomers (Flitney, 2007). Nevertheless the advantages of biodiesel superseded the disadvantages generally on the environmental aspects, making it very popular alternative to petroleum derived-diesel oil.